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Research on Prevention Effect of Grain Pest by CO_2 Controlled Atmosphere

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Abstract: The total 30 million kilos grain reserves project by CO_2 controlled atmosphere in our warehouse is invested and built by the state and was entirely finished in December 2002. CO_2 controlled atmosphere warehouse test was conducted from May to August in 2004, so as to give full play to the advantages of grain storage by CO_2 controlled atmosphere, which are pest disinfestations, bacteria inhibition, extension of the quality of reserved grain, without residue, pollution and public hazard. The test indicated that applying above 35% CO_2 in high flat warehouses for 15 days, grain can effectively be disinfested of stored – grain pests, postpone the rate of deterioration of reserved grain and realize the safe reserve of Grain Reserves of Central Government.

Key words: CO_2, Controlled atmosphere, Stored – grain pests, Prevention and control

Introduction

CO_2 controlled atmosphere storage technology is the grain storage method to output liquid CO_2 from fixed CO_2 gas storage, increasing the air tightness seal of warehouses, adopting a centralized gas supply method and utilizing manufacturing facilities of controlled atmosphere, then conveying the gas into controlled atmosphere warehouses through gasification and decompression. Then raise the CO_2 level in the warehouse to the treatment concentration rapidly and evenly through forced recirculation piping systems. Finally, using computerized technology to automatically check CO_2 concentrations in warehouses to keep it within the specified treatment range, so as to preserve grain by a suitable, clean controlled atmosphere. CO_2 can control stored – grain pests, inhibit occurrence and development of mold of reserved grain, postpone deterioration of reserved grain, decrease the cyclic frequency of insect infestations and phosphine fumigations, abate the harm to humans and damage to ecological environment, reduce pollution of reserved grain, increase the economic value of reserved grain, and realize the environment – friendly and safe storage of grain.

Lu'an Warehouse carried out stored warehouse test of grain reserves by CO_2 controlled atmosphere, which focused on carrying out primary research in terms of pest disinfestations effect of CO_2 controlled atmosphere, variation situation of grain quality and safe operation, compared to regular grain reserves. The test situation is as follows:

1 Basic Situation of Tested Warehouse

Select the No. 18 CO_2 controlled atmosphere warehouse to conduct stored warehouse gas charging test form May 26th, 2004 to the end of August, 2004. The 60 24m arch large flat warehouse reserved medium and late indica rice produced in 2003 with 6.0m stack height, moisture 13.4%, impurity 1.0%, fatty acid value 17.6mgKOH/100g, upper grain temperature of 13.6℃, lower grain temperature of 6.8℃, and average temperature of 11.6℃. The stored – grain pests are sitophilus zeamais and cryptolestes pusillus, with the total density of 6 insects/kilo.

2 Test Materials and Preparation

2.1 Safe operation and notes

Spray 5cm polyurethane foam on the surface of the lower panel of the arch panel of the warehouse to insulate heat before the test. Adopt special hermetic heat preserving door and window and vent sleeve with the silicone rubber sealing strip and the lever locking device. Instead of the ordinary interior wall coating, adopt polyamide epoxy resin coating as the hermetic seal coating. Adopt sealing materials such as caulking glue, polyurethane paint and epoxy resin to conduct sealing process for various slots such as holes in doors and windows, access of

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air pipe and the slot on structure base slab, connecting joint between interior wall and concrete base slab top, and internal angle of interior wall. The warehouse air tightness test on May indicated that the half-life period of decompression from 500Pa to 250Pa is 314 seconds.

2.2 Carry out System

From March to May, 2004, our warehouse cooperated with the project design institute and construction institute to carry out system adjustment for the gas transmission system, gas supply system, detection system, decompression system and computer automatic control system, no-load linkage trial run and stored warehouse linkage trial run of CO_2 controlled atmosphere warehouse. All the systems were in stable operation according to the test.

2.3 Pre-embed the Test Pests

On May 26th, 2004, under the guidance of the technicians in Chengdu Grain Storage Research Institute, insect test sample containers were pre-embeded according to the pest control test plan of CO_2 controlled atmosphere storage. This included a total of 10 groups of stored – grain pests separately containing 3 kinds of sensitive species and resistant species in each pest state (adult, egg, larva, pupae) with the appropriate food type and quantity for the insects during the test period.

2.4 Controlled Atmosphere System Map

The debugging of pipe, gate valve, monitoring system software and appliance in CO_2 air holder was normal (Figure 1).

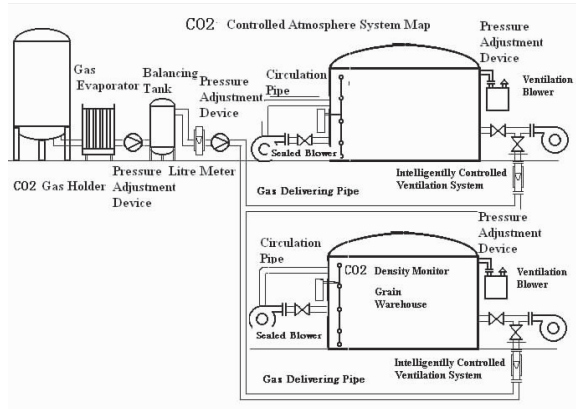

Fig. 1 CO_2 Controlled Atmosphere System Map

Table 1. Testing Record of Air – tightness of Empty CO_2 Controlled Atmosphere Grain Warehouse

Warehouse No.: 18 | Half Life Period of Pressure: 536 sec | Warehouse Type: arched – slab flat warehouse
Variety of Grains Stored: / | Height of Grains Stored: /m | Surrounding Wind Speed: 1 m/sec
Relative Humidity: 67 % | Warehouses Temp.: 16 ℃ | Surrounding Temp.: 12 ℃
Testing Method: EmptyP – T Positive Pressure Method, test the pressure half life period of 500Pa – 250Pa Air Pressure: 1.013×10^5 Pa

	First Sealing Press. Test			Second Sealing Press Test			Third Sealing Press. Test		
1	2	3	1	2	3	1	2	3	
P_{max} (Pa)	700	700	700	700	700	700	700	700	700
t_{mn} (s)	523	532	532	512	538	556	542	550	541
$t_{m/ave}$ (s)		529			535			544	
Δt (s)	6	3	3	23	3	21	2	6	3
ψ (%)	1.13	0.57	0.57	4.3	0.56	3.93	0.37	1.10	0.55
$t_{1/2}$ (s)					536				

Conclusion and Analysis: The air – tightness of the warehouse conforms to the design requirements at 5 minutes.

Table 2. Filled Testing Record of Air – tightness of Stored CO_2 Controlled Atmosphere Grain Warehouse

Warehouse No.: 18 | Half Life Period of Pressure: 317 sec | Warehouse Type: arched-slab flat warehouse
Variety of Grains Stored: Late indica Rice | Warehouses Temp.: 5 ℃ | Surrounding Temp.: 3 ℃
Height of Grains Stored: 6.0 m | Relative Humidity: 84 % | Surrounding Wind Speed: 2.7 m/sec
Testing Method: P – T Positive Pressure Method, test the pressure half life period of 500Pa – 250Pa Air Pressure: 1.013×10^5 Pa
Testing Method: P – T Positive Pressure Method, test the pressure half life period of 500Pa – 250Pa

	First Sealing Press. Test			SecondSealing Press. Test			Third Sealing Press. Test		
1	2	3	1	2	3	1	2	3	
P_{max} (Pa)	580	580	600	600	600	600	580	600	600

	First Sealing Press. Test			SecondSealing Press. Test			Third Sealing Press. Test		
t_{mn}(s)	324	318	316	312	324	320	308	320	311
$t_{m/ave}$(s)		319.3			318.7			313	
Δt (s)	4.7	1.3	3.3	6.7	5.3	1.3	5	7	2
ψ (%)	1.5	0.4	1	2.1	1.7	0.4	1.6	2.2	0.6
$t1/2$(s)					317				

Conclusion and Analysis: the air – tightness of the warehouse conforms to the design requirements at 5 minutes.

Notes: meaning of symbols in the table and calculation formulas

1. P_{max} – test the max value of the warehouse bulging pressure, unit: Pa;
2. t_{mn} – pressure half life period of No. n test in No. m hermetization, unit: sec;
3. tm/ave – average value of pressure half life period in No. m hermetization, tm/ave = (tm1 + tm2)/2, unit: sec;
4. Δt— deviation of pressure half life period, $\Delta t = |t_{mn} - t_{m/ave}|$, unit: sec;
5. ψ — deviation coefficient of pressure half life period, $\psi = \Delta t / t_{m/ave}$;
6. $t_{1/2}$ — effective value of warehouses pressure half life period, $t_{1/2} = \sum t_{mn}/n'$, unit: sec;
7. When calculating the $t_{1/2}$ value, bring the tmn value of $\psi \leq 10\%$ calculated in each measurement into the summation (∑) of t1/2, n′ means the times of tmn value's entering t1/2 summation, and $n' \geq 3$.

2.5 Calculation of Theoretical Gas Consumption

$$Mco_2 = [1.1Cco_2(NVb + VHS) + SVbPb/\rho co_2]/[571(m^3)/ton] = 13.39 \text{ ton}$$

2.6 Gas charging procedure

Table 3. CO_2 Density Change Data table during Pest Killing by Charging Gas in Stored Warehouse

Testing date	Minimum CO_2 density %	Testing date	Minimum CO_2 density %
2004 – 6 – 2	32.0	2004 – 6 – 11	42.8
2004 – 6 – 3	35.8	2004 – 6 – 12	46.6
2004 – 6 – 4	39.2	2004 – 6 – 13	45.1
2004 – 6 – 5	45.1	2004 – 6 – 14	42.4
2004 – 6 – 6	46.3	2004 – 6 – 15	45.7
2004 – 6 – 7	44.5	2004 – 6 – 16	42.5
2004 – 6 – 8	45.9	2004 – 6 – 17	39.6
2004 – 6 – 9	45.0	2004 – 6 – 18	42.1
2004 – 6 – 10	43.5	2004 – 6 – 19	42.0

Test grain condition—open valve of charged warehouse — start charging—stop charging when minimum density is more than 35%—open gas recirculation system — recharge gas slowly when average density is less than 75% – regularly test and ensure the time when minimum density is over 35% shall be over 15 days.

3 On-site Operation and Testing

3.1 Formally started first gas charging at 17:00 pm on May 26, 2004 and stopped at 16:00 pm on May 27 2004; 8.39 tons gas discharged in first filling period with CO_2 density of 1% – 86%; due to the minimum density < 35%, continued charging 4.1 tons gas from 20:00 pm, June 1 to 7:00 am June 2, 2004 with CO_2 density of 32% – 91%; supplement 1.1 tons CO_2 gas in small fills twice – on June 3rd and 12th with 35.8% CO_2 density at the minimum point. The test in this time totaled 13.59 tons CO_2 gas charged into No. 18 warehouse.

3.2 After gas charging, immediately start fixed internal gas recirculation system to evenly mix the CO_2 air density in the warehouse.

3.3 Finish test data record before and after the gas charging of stored warehouse separately, record the operation data of each appliance every two hours during the process of gas charging, mix evenly after gas charging, and record test data one time each day. The specific method sees to Table 1 and Fig. 2.

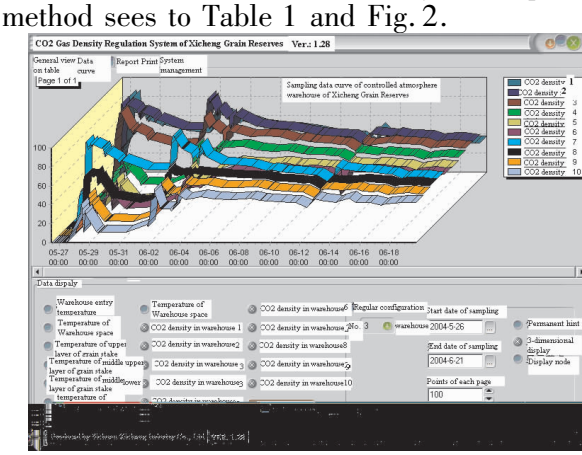

Fig. 2 CO_2 Density Change Curve during Controlled Atmosphere Storage

3.4 Delivered the pest samples to technical supporting institute, Chengdu Grain Storage Research Institute, for test on June 18th 2004 when the lowest CO_2 density in the warehouse had remained above 35% more than 15

days.

4 Analysis of Test Effect

4.1 During controlled atmosphere grain reserves test, the air tightness of stored warehouse was 5 min. and 14 sec. which is longer than the designed standard of 4 min., indicating that the air tightness of this warehouse exceeded the designed requirement.

4.2 The test data indicated that the time when CO_2 density remaines above 35% in each point of the warehouse reached 22 days, which was 7 days longer than the technical standard of over 15 days.

4.3 Pest killing result in stored warehouse: The test conducted by Chengdu Grain Storage Research Institute indicated that 10 – group trial stored grain pests (including each pest status of sensitive species and resistant species) were completely killed, and that the pest killing effect for stored grain pests reached 100% by using CO_2 with 75% – 35% density for more than 15 days.

4.4 The influence of controlled atmosphere storage on grain quality: Opened the warehouse to disseminate gas for 3 months after gas charging. Fatty acid value was 18.1mgKOH /100g by testing selected samples, which increased 0.5, and fatty acid value of regular warehouse at the same time increased relatively fast from June to August, increased 1.5 average, which indicated that under the same storage conditions, the increase of fatty acid value in late indica rice stored by controlled atmosphere storage was 1.0 less than regular warehouse.

5 Benefit Comparison Between CO_2 Controlled Atmosphere Storage and Regular Storage

After the test, we carried out comparison and analysis on the operation expenses of CO_2 controlled atmosphere storage in stored warehouse and that of regular grain storage, and found that gas consumption quantity for controlled atmosphere stored grain is 2.72 kg/year per ton, operation expenses was RMB 2.56/year per ton, which reached the anticipated target of = 3 kg/ton per year and criteria for evaluation of = RMB 4/ton per year.

The average price of grain that is stored by adopting new technology can increase RMB30/ton; realize newly-added benefit above RMB 25/ton. Ten thousand tons grain stored by controlled atmosphere for 3 years can newly add benefit of RMB 83.2 thousand.

Table 4. Benefit Comparison Table between CO_2 Controlled Atmosphere Storage and Regular storage

Serial No.	Compared items		Regular warehouse	Controlled atmosphere warehouse
1	Species		Paddy	Paddy
2	Tonnage (ton) of grain reserves		5016	5000
3	Main materials	CO_2		10880
		PH_3	864	/
4	Assistant materials		4500	500
5	Health care (assistance by medicine)		1000	/
6	Electricity Consumption		50	850
7	Warehouse repair	Material	/	400
		Labor expenses	/	150
8	Subtotal of operation expenses		6414	12780
9	Annual gas consumption (Kg) for grain reserves		0.0072	2.72
10	Annual operation expenses for grain reserves		1.28	2.56
11	Custody expenses per ton		78	78
12	Operation expenses/ custody expenses per ton		1.64%	3.28%

Note: (1) The additional materials needed for regular warehouse during grain storage are mainly sealing film for sealing doors, windows and grain surface, attached gland materials and fumigant pipe for grain stack. Convert to the expenses in one year according to their service life; doors and windows were sealed and grain surface was not sealed in controlled atmosphere warehouse.

(2) The AlP fumigation for regular stored grain was accounted as once per year, and that for controlled atmosphere stored grain was accounted as per CO_2 gas charging once every year.

(3) Circulation fumigation for regular stored grain adopted AlP under film dynamic deliquescence method, without using CO_2 gas in steel cylinder. AlP was RMB 24/kilogram; liquid CO_2 for controlled atmosphere storage was RMB 800/ton.

6 Analysis and Discussion

6.1 Analysis of pest killing effect

Compared with regular grain storage method, CO_2 controlled atmosphere storage can effectively kill stored-grain pests so as to achieve the purpose of inhibiting breath of grain and postponing quality change, and solve the difficult problems of excessive reliance on aluminium phosphide fumigation agent and increase of pest resistance to AlP at present in conventional grain storage which result in significant increase of AlP quantity. Use of CO_2 can resolve pest control difficulty caused by human behavior of ineffective AlP fumigations, while effectively

preventing grain and environment pollution from AlP , and provide new method for inhibiting the AlP resistance of stored – grain pests.

6.2 Analysis of Economic Benefit

The newly-added cost for controlled atmosphere storage technology is less than RMB 4/ton. year(minus fumigation cost of RMB 1/ton. year). Compared to regular storage technology, controlled atmosphere technology can greatly increase the added value of product as it can keep the application quality of grain and inhibit the damage losses from pests and molds.

6.3 Analysis of Social Benefit

CO_2 controlled atmosphere storage technology is one of the environment-friendly technologies generally recognized by the world, so that the parent company has determine to realize the target of above 50% environment-friendly grain storage. Controlled atmosphere storage is one of the effective methods in the high-temperature and high-humidity regions of South China. The successful application of this technology not only can upgrade the technological storage level of China Grain Reserves Corporation, but also can enhance and fully establish the image of China Grain Reserves Corporation as a world grain leader, and promote the status of our country in worldwide grain markets, import and export trade, and technology exchange.

6.4 Problems and Experiences

CO_2 controlled atmosphere storage can kill all life stages of pests and minimize the deterioration of grain quality; however, when compared to regular warehouse, first, operation cost is relatively high, second, it increases CO_2 emissions, third, repair expenses for maintaining high levels of air tightness of warehouse is high. In our opinion, advantages are much greater than disadvantages. Killing pests by controlled atmosphere must ensure that warehouse is provided with favorable air tightness and adopt the safety measures such as effective gas protection.

6.5 Safe Operation and Notes

To get excellent air-tightness of warehouse, it is necessary to be strict during the construction of the main project and supervise the construction quality of key parts like sealing junctions of walls, floors and arched slab as well as around doors, windows, piping, electrical wiring, etc. When the installation of CO_2 storage and vaporizing system is finished, airtight experiments with dry and oil-free air or nitrogen shall be performed on it, to check if there is leakage of pipes and valves under working pressure. The experiment procedure shall comply with *Pressure Vessels Safety and Technical Supervision Regulation* of the State Administration of Quality and Technical Supervision.

All pressure equipment and electrical installation are classified as high-voltage, hazardous equipment, so the relevant operation and maintenance should be conducted by trained, licensed and certified professionals. There should be the obvious warning sign on the site of installation and operation.

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